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The European lesser glow worm, *Phosphaenus hemipterus* (Goeze), in North America (Coleoptera, Lampyridae)

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Abstract

Phosphaenus hemipterus (Goeze) is a Palaearctic glow worm (Coleoptera: Lampyridae), previously been reported in North America on the basis of two specimens; one collected in 1947 in Yarmouth, Nova Scotia; the other in 1989 in Montréal, Québec. The present study newly records it from three sites in Halifax, Nova Scotia. One hundred and twenty six adult males and larvae were collected in 2009 in disturbed urban grassland areas, similar to habitats in England and Belgium where the species has been investigated. Experiments confirm that larvae feed on earthworms (*Lumbricus terrestris*), consistent with observations in Europe. The habitat is described, including vegetation, potential predators, and prey. Although ballast-shipments have previously been proposed as a vector for the species' introduction to North America, the present study suggests that the importation of agricultural and horticultural products, which has lead to the introduction of many earthworms to the continent, could also serve as a conduit for the introduction of obligate earthworm predators such as the larvae of *P. hemipterus*. Although an adventive species, possible conservation concerns are discussed for a species that is considered endangered in parts of its native range.

Keywords

Coleoptera, Lampyridae, *Phosphaenus*, adventive species, bionomics, conservation, urban ecology, Nova Scotia, Canada

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Introduction

Phosphaenus hemipterus (Goeze, 1777), the lesser glow worm, is an unusual member of the Lampyridae (fireflies). It is a European species recorded in Austria, Belgium, Crete, Czech Republic, Denmark, Estonia, Finland, France, Germany, Italy, Latvia, Lichtenstein, Lithuania, Luxembourg, Macedonia, Netherlands, Poland, Romania, central, western and northwestern Russia, Slovakia, Slovenia, Spain, Sweden, and Switzerland (De Cock 2000; Geisthardt 2007; GBIF 2009). In England, the species has been collected at several sites in East and West Sussex, Hampshire, and Surrey from 1868 to the present (Rye 1868; Jenner 1883; Denton 1996; De Cock et al. 2007, in press; GBIF 2009). In Belgium De Cock (2000) found that the species inhabits habitats with loamy soils and abrupt transitions from dense vegetation to bare areas such as those found in gardens, parks, car parks and field edges. The status of the species in England is still subject to some question, however, De Cock et al. (in press) present a convincing argument that *P. hemipterus* is an adventive species, noting that virtually all of the records are close to the coastline and clustered around towns with seagoing connections.

Phosphaenus hemipterus is an unusual species in several regards. In contrast to most lampyrids, which are nocturnally active, adults are diurnal (De Cock 2000). Furthermore, it is the only one of the more than 2,000 species of lampyrids in which both females and males are flightless (De Cock 2000). Lampyrids fall into three biological groups (Lloyd 2002):

1) "fireflies" in which males emit precise flashing patterns to attract the attention of females (e.g., North American species in the genera *Photinus, Pyractomena,* and *Photuris*, all of which are found in Atlantic Canada);

2) "glow worms" in which females are bioluminescent and males are almost exclusively non-bioluminescent, but have large eyes to locate the glowing females (e.g., North American species in the genera *Pausis, Microphotus,* and *Pleotomus*, none of which occur in Atlantic Canada). In many "glow worm" species, females are brachypterous, apterous, or larviform, however males are always macropterous, searching aerially for females; and

3) "daytime dark fireflies" which are non-bioluminescent species that employ pheromones for sexual communication and are frequently diurnally active (e.g., North American species in the genera *Ellychnia, Lucidota,* and *Pyropyga*, all of which are found in Atlantic Canada).

In this regard, *P. hemipterus* appears to be anomalous; both sexes are feebly bioluminescent (although they appear only to glow in response to disturbance); females are apterous; males are brachypterous and incapable of flight, and also have very small eyes (Fig. 1). Consequently the possibilities of employing visual signals for sexual communication are very limited. De Cock and Matthysen (2005) demonstrated that males are able to locate females from distances as great as 20 m in a downwind direction, presumably sensing pheromones with their large antennae. Males have been observed to climb grass stalks and wave their antennae before returning to the ground in search

Figure 1. An adult male specimen of *Phosphaenus hemipterus* (photographed in Switzerland). Note the broad antennae, small eyes, lampyrid-shaped pronotum, and the shortened elytra exposing seven abdominal segments, the last two bearing bioluminescent organs. Photo credit: Urs Rindlisbacher.

of females (De Cock et al. in press). Although Branham and Wenzel's (2003) cladistic analysis of the Lampyridae places *P. hemipterus* within the "daytime dark fireflies", it is, however, bioluminescent. In all these regards *P. hemipterus* is an unusual lampyrid.

It is also the only lampyrid to have been introduced to North America. Brown (1950) reported a single male in Yarmouth, Nova Scotia in 1947 [5 July 1947, Yarmouth, NS, W.J. Brown, evening sweeping in meadow at edge of town, Canadian National Collection]. Subsequently McNamara (1991) recorded the species from Québec [Mount-Royal, Montréal, 20 June 1989, Serge Laplante, at the base of the trunk of an old living *Quercus rubra,* Serge Laplante collection]. Downie and Arnett (1996, 848) listed it from «Ontario ?», however, this appears to have been the result of an error since there are no reports of this species from that province. Until recently, this was all that was known about this species in North America. In the present paper we report further information on its occurrence in Nova Scotia.

Site descriptions

Phosphaenus hemipterus was found in three neighbouring sites in Halifax, Nova Scotia, Canada: 1) Fort Massey Cemetery (44° 38' 23" N, 63° 34' 28" W); 2) Holy Cross Cemetery (44° 38' 19" N, 63° 34' 34" W); and 3) a nearby partial-lawn/partial-garden

site above a parking garage and adjacent to an apartment building (44° 38' 26" N, 63° 34' 26" W) on Queen Street (hereafter referred to as the "Queen St." site).

The Fort Massey site is situated along an elevated slate ridge. It largely consists of a mowed grassy area with scattered large horse chestnuts *Aesculus hippocastanum* L., Hippocastanaceae), a large-toothed poplar (*Populus grandidentata* Michx., Salicaceae), and ash (*Fraxinus* sp., Oleaceae) trees. There is a gravel footpath and a bounding concrete wall that separate the site from the adjacent street (Fig. 2).

The Holy Cross site is along a slope and in a lower area below this ridge. It has scattered horse chestnut, ash, Norway maple (*Acer platanoides* L., Aceraceae), American elm (*Ulmus americanus* L., Ulmaceae), linden (*Tilia europaea* L., Tiliaceae), willow (*Salix* sp., Salicaceae), and red oak (*Quercus rubra* L., Fagaceae) trees. There is a gravel track that winds through the site, and patches of bare earth (Fig. 3). The ground cover in both areas is similar consisting of grasses (Poaceae), with a mixture of hawkweeds (*Hieracium* sp.), dandelion (*Taraxacum officinale* Weber), fall dandelion (*Leontodon autumnalis* L.), yarrow (*Achillea millefolium* L.) (Asteraceae), yellow wood-sorrel (*Oxalis stricta* L., Oxalidaceae), common plantain (*Plantago major* L., Plantaginaceae), and tall buttercup (*Ranunculus acris* L., Ranunculaceae) scattered amongst them. Soils are moist and loamy.

The Queen St. site consists of two strips of lawn built on top of a one-storey parking garage over 20 years ago. Water drains poorly from one of the strips of lawn, and after a rainfall it can remain damp for a period of time. The site has scattered Norway

Figure 2. Photograph of the habitat at the Fort Massey site where *Phosphaenus hemipterus* specimens were collected. Foraging birds, such as the American Crow (*Corvus brachyrhynchos*) in the foreground, could be potential predators of diurnal beetles such as *P. hemipterus*. Photo credit: Christopher Majka

maple, ash, and scots pine (*Pinus sylvestris* L.,) (Pinaceae), a hedgerow of English yew (*Taxus baccata* L.) (Pinaceae), and scattered planted bushes of eastern redcedar (*Juniperus virginiana* L. (Pinaceae), red-osier dogwood (*Cornus sericea* L., Cornaceae), goldflame spiraea (*Spiraea japonica* L.f.), and fly-honeysuckle (*Lonicera canadensis* Bartr., Caprifoliaceae). There are some planted ornamental flowers, however, the ground cover consists primarily of grasses with a mixture of dandelion, fall dandelion, common plantain, tall buttercup, clovers (*Trifolium* sp., Fabaceae), violets (*Viola* sp., Violaceae), and field speedwell (*Veronica agrestis* L., Scrophulariaceae). There is a paved walk and bounding concrete wall (in some areas) in addition to the concrete wall of the apartment building (Fig. 4). In one area there is a heap of grass cuttings, pine needles and other vegetative material raked from the site that is overgrown with deadly nightshade (*Solanum dulcamara* L., Solanaceae).

Results

Between 3–24 July 2009, in the course of research on the insect fauna of green roofs and adjacent areas in Halifax, 122 adult males *Phosphaenus hemipterus* were collected in pitfall traps. They were all collected at the Fort Massey and Queen St. sites. Specimens are presently in the collections of the authors; voucher specimens will be deposited in

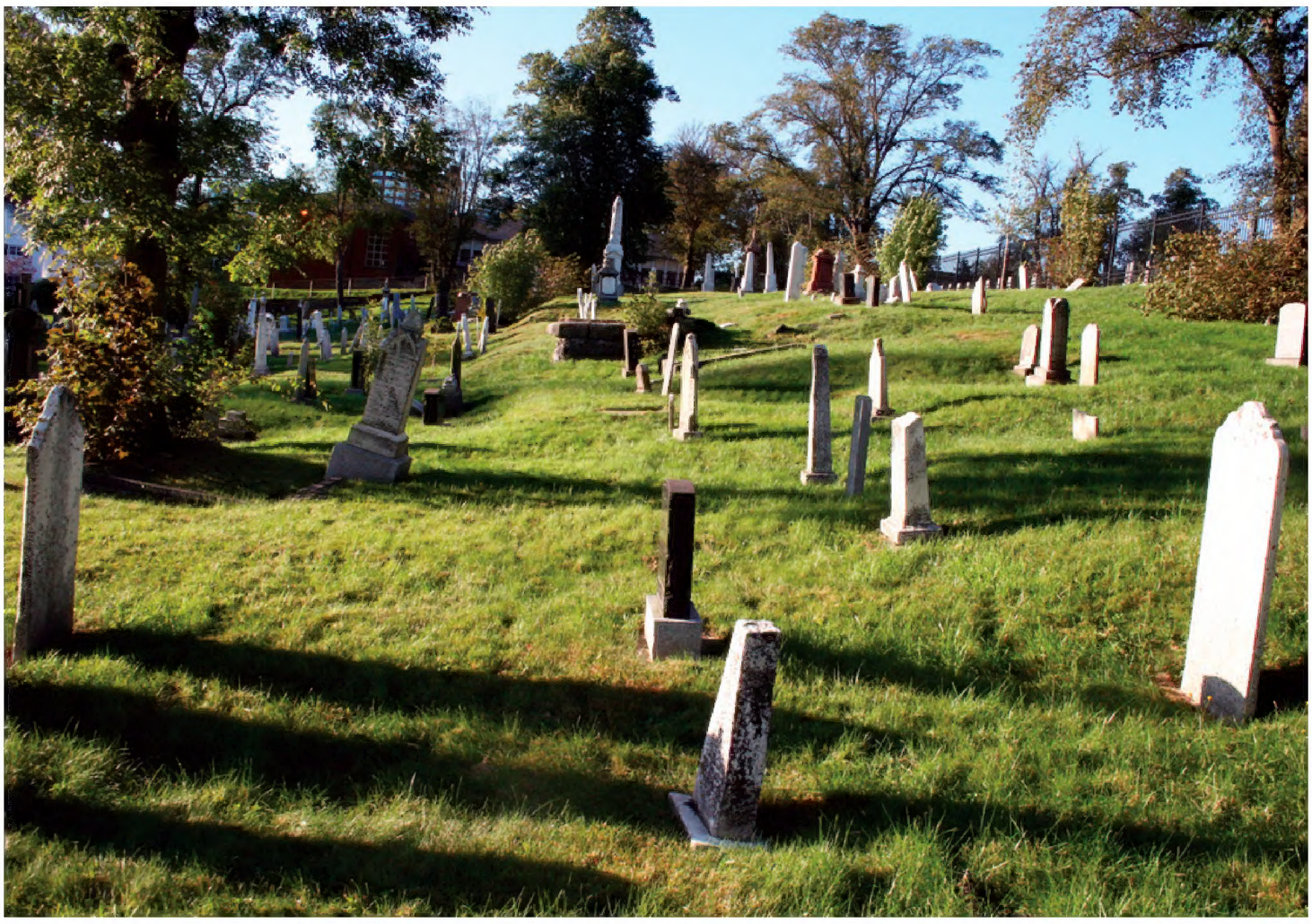

Figure 3. Photograph of the habitat at the Holy Cross site where *Phosphaenus hemipterus* specimens were collected. Photo credit: Christopher Majka

Figure 4. Photograph of the habitat at the Queen St. site where *Phosphaenus hemipterus* specimens were collected. Note the concrete wall of the apartment building directly abutting on the lawn area. In the foreground is the trunk of an ash tree, and a row of shrubs consisting of goldflame spiraea, fly honeysuckle, red-ozier dogwood, and eastern redcedar. Photo credit: Christopher Majka

the Nova Scotia Museum and Canadian National collections. On 9 September 2009, over a span of six hours, four *P. hemipterus* larvae were collected at the Fort Massey site and the adjacent Holy Cross site. These were found in the earth at a depth of ~ 8 cm beneath one of the pitfall traps under a horse chestnut, and under a rock in a pile of stones beneath a Norway maple (Fig. 5).

The soil was also investigated for possible predators of *P. hemipterus* and potential prey species that could be utilized by *P. hemipterus.* At all three sites *Lumbricus terrestris* L. (Lumbricidae), an adventive European earthworm, was abundant. In experiments in the lab, larvae in an artificial habitat of earth and moss constructed in a Petri dish, attacked and consumed a specimen of *L. terrestris* that had been released into the vessel (Fig. 6). Also common at all three field sites were three species of terrestrial gastropods: *Hygromia hispida* (Linnaeus) (Helicidae) and *Oxychilus cellarius* (Müller) (Oxychilidae), Palaearctic land snails, adventive in North America; and *Cionella lubrica* (Müller) (Cionellidae), a widely distributed Holarctic species (Davis 1992). Voucher specimens will be deposited in the Nova Scotia Museum.

At all three sites we found *Carabus nemoralis* Müller, an adventive Palaearctic carabid which is a large generalist predator that feeds on slugs (mostly), earthworms, caterpillars, and other insects and invertebrates (Larochelle and Larivière 2003); and *Xantholinus linearis* (Olivier) and *Philonthus cognatus* Stephens, both adventive Palae-

Figure 5. The collection locale of the *Phosphaenus hemipterus* larvae in the Holy Cross site in a rock pile. Note the rock wall in the background. Photo credit: Christopher Majka.

Figure 6. A *Phosphaenus hemipterus* larvae feeding on an earthworm (*Lumbricus terrestris*). While feeding, the tarsal claws of the legs anchor the larva to the body of the earthworm and the extended antennae move over the surface of the earthworm's body. Photo credit: Christopher Majka.

arctic staphylinids found in many disturbed habitats and in decaying matter (Smetana 1982, 1995). At the Fort Massey Site, we additionally found *Carabus granulatus hibernicus* Lindroth, another adventive Palearctic carabid that feeds on snails (mostly), earthworms, and insects (Larochelle and Larivière 2003); *Anotylus rugosus* (Fabricius) an omaliine staphylinid (either adventive Palaearctic or native Holarctic) which feeds on vegetative matter but is also a facultative predator (Hammond 1976); and *Gabrius picipennis* (Mäklin) a native staphylinid which occurs in a wide variety of habitats (Smetana 1995). All these species could be potential predators of *P. hemipterus* adults or larvae. Other potential predators would presumably be avian ones such as European Starlings (*Sturnus vulgaris* L.) or American Crows (*Corvus brachyrhynchos* Brehm) that commonly forage in these locations.

Discussion

The sites at which the adults and larvae were collected are strikingly similar to many of the habitats in which *P. hemipterus* has been found in Belgium and Great Britain (De Cock 2000; De Cock et al. in press); namely, partially disturbed anthropogenic sites with lawn areas, mixed patches of shrubs, hedgerows, some trees (or a proximity to forested areas), hardened paths, spots of bare earth – and particularly – a proximity to concrete or rock walls and/or paved areas. One of the sites in Belgium has a similar composition of trees (*A. hippocastanum, Quercus spp., Acer pseudoplatantus*) to the Fort Massey and Holy Cross sites, and in Montréal *P. hemipterus* was collected at the base of a *Quercus rubra* tree. In Great Britain *P. hemipterus* has also been collected from churchyards (De Cock et al. in press). In Belgium, De Cock (2000, 97) wrote, "In all areas, the males mostly crawled on roads, paths, and especially along kerbs and road borders, or at the base of walls ...." De Cock (2000) concluded that the assumed rarity of this species in many parts of Europe might be the result of its preferring disturbed habitats not favoured by contemporary entomological investigations. Given the anthropogenic habitats that *P. hemipterus* currently inhabits, one might wonder what its original environmental preferences were. Larson et al. (2004) argued that many synanthropic species were originally cliff dwellers. Given the proclivity that males have for concrete and rock walls and kerbs, *P. hemipterus* might be a suitable candidate for having ancestrally inhabited such habitats.

Also, in keeping with experimental studies and field observations in both Belgium and Great Britain (De Cock 2000; De Cock et al. in press), *P. hemipterus* larvae were observed to feed on earthworms (adults do not feed). De Cock (2000) presented larvae in Belgium with a variety of slugs and snails that are the favoured prey of other species of European lampyrids, however, these were always ignored by the *P. hemipterus* larvae.

The extent of the distribution of *P. hemipterus* in Halifax remains to be determined. All three sites are within 0.3 km of one another, however, there are many other neighbouring private gardens, public parks (Victoria Park, the Halifax Public Gardens) and cemeteries (Camp Hill Cemetery, the Old Burial Grounds) that have similar habitats,

and which have not been investigated for *P. hemipterus*. Although a paved street might appear to be a significant obstacle to dispersal for a flightless, diurnally active beetle, the Queen St. site is on the opposite side of a four-lane street from the two other sites, thus indicating that the species has some ability to overcome such barriers.

Nonetheless, in comparison to other species of Coleoptera, the dispersal abilities of *P. hemipterus* are limited. Consequently the population in Halifax must represent a separate introduction event from specimens collected in Yarmouth, Nova Scotia (220 km distant) and Montréal, Québec (800 km distant), implying that the species has been introduced to the continent on at least three separate occasions (Fig. 7). The mechanism and timelines of these introductions are far from apparent.

The earliest date of detection of this species in North America is 1947 in Yarmouth (Brown 1950). Brown (1950) noted that large quantities of dry ballast were imported to Atlantic Canada from Europe commencing with the Napoleonic Wars (1803–1815) and in this context highlighted Yarmouth as a historic port town. This idea was taken up in considerable detail by Lindroth (1957) who investigated the topic through (amongst other things) conducting surveys of the flora and fauna of the eight principal

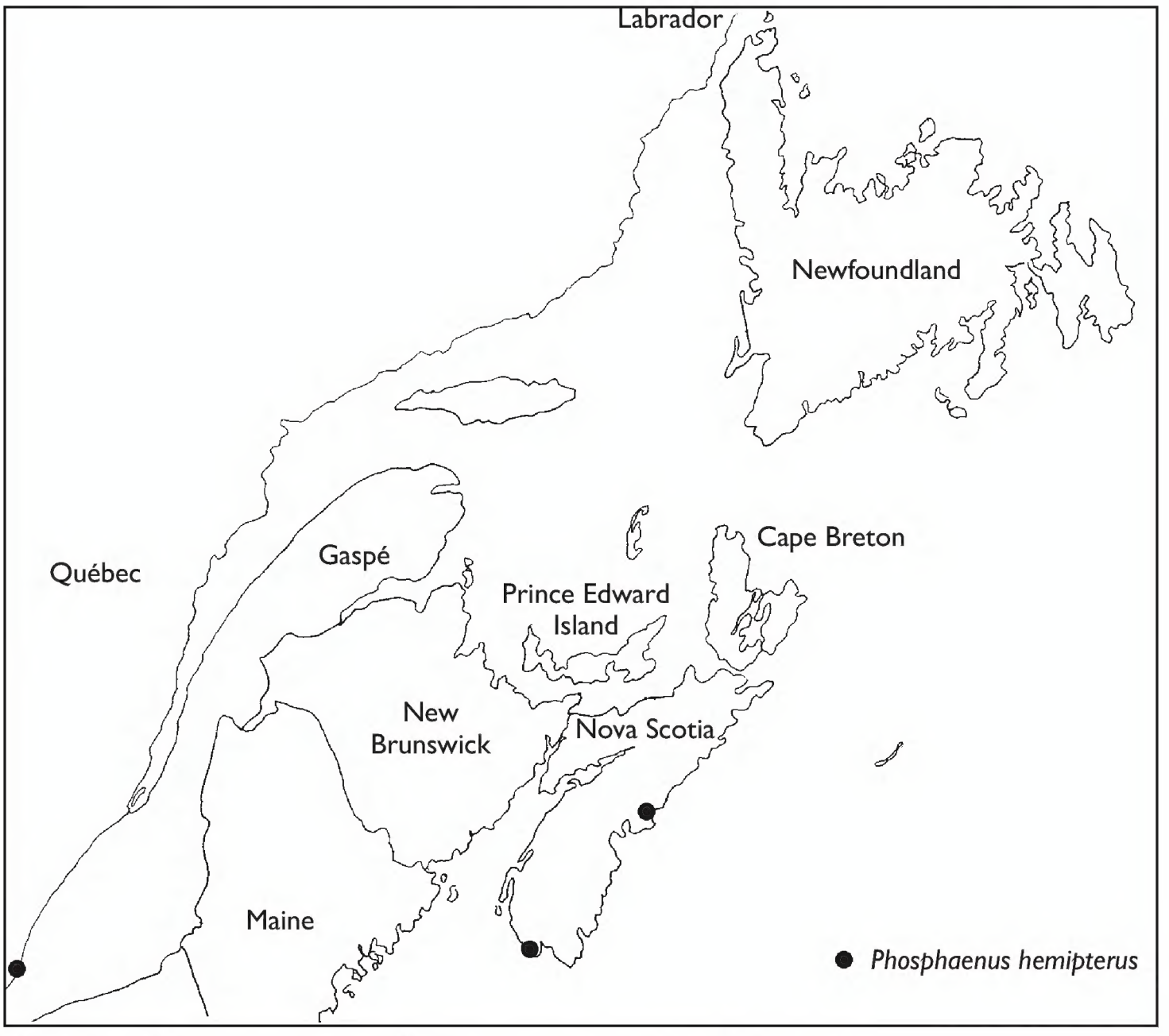

Figure 7. Collection localities for *Phosphaenus hemipterus* in North America.

sites in Great Britain (in North and South Devon, Dorset, and Somerset) where dry ballast destined for Atlantic Canada originated. None of these sites, which are all along the southwestern coast of England, are in the southeastern area of the English coastline where *P. hemipterus* is known, and indeed, Lindroth (1957) did not find it in his surveys (although in Bristol, Somerset, he did find larvae of *Lampyris noctiluca* L., the other species of glowworm found in Great Britain).

The association of *P. hemipterus* with earthworms suggests another possible vector for its introduction. In Canada, 19 of the 25 species of earthworms found in the country are adventive species (Reynolds 2009). The only native species in Canada are those that survived the Wisconsinian glaciation in glacial refugia in British Columbia. Hendrix and Bohlen (2002) noted that monitoring in the United States has shown that exotic earthworms are continually being imported in a variety of plant-associated materials (mostly soil) in association with a variety of agricultural and horticultural products. Majka and Klimaszewski (2004) reviewed adventive Coleoptera imported to North America through the port of Halifax and highlighted species such as *Chrysolina staphylaea* (Linnaeus) (Chrysomelidae), *Meligethes viridescens* (Fabricius) (Nitidulidae), and *Popillia japonica* Newman (Scarabaeidae) that were apparently imported to Halifax in association with horticultural products. They also pointed out that in 1878, 1894, and 1935–37 over 10,000 seedling trees (presumably with associated soil) were imported from European tree nurseries and planted in Point Pleasant Park in Halifax. Presumably the same mechanisms that have served to introduce adventive earthworms to Canada could also potentially serve to import associated obligate earthworm predators such as the larvae of *P. hemipterus*.

Although considered adventive in Great Britain, *P. hemipterus* is nevertheless included in the British Insect Red Data Book (Shirt 1987) as a species in particular need of protection. It is uncommon in many areas of Europe where it occurs, and is Red Listed in Germany as an endangered species (Geiser 1998). De Cock (2000), however, argued that it may have be overlooked in many European jurisdictions as a result of favouring urban habitats, areas not generally investigated in glow-worm surveys. In general, concerns have been articulated for the past 40 years about the decline of populations of European glow worms (Wootton 1971). Consequently, the discovery of an apparently flourishing population of *P. hemipterus* in Nova Scotia, is noteworthy and could merit some degree of conservation.

Although it possesses very limited dispersal abilities, *P. hemipterus* appears to thrive in a variety of disturbed anthropogenic environments of the kind that are plentiful in a city such as Halifax. It feeds on adventive earthworms that are also abundant in the city. Furthermore, in 2003 the Halifax Regional Municipality enacted a pesticide bylaw (P-800) which bans "the application and use of pesticides for the maintenance of out door trees, shrubs, flowers, other ornamental plants and turf on the part of a property used for residential purposes or on a property of the municipality," thus eliminating a potential threat to the survival of many insects and invertebrates.

Further fieldwork to determine the extent of the distribution of this species in Halifax is warranted, as is the possibility of interpretative and education programs that

would draw attention to this unusual species within the municipality. No survey work has been conducted in Yarmouth, Nova Scotia since 1947 to determine if *P. hemipterus* still survives there, nor have other seaport towns in Nova Scotia been investigated to ascertain if *P. hemipterus* occurs more widely in the province. Although the present discovery adds considerably to the knowledge of this species in North America, it is clear that much more remains to be discovered.

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